A 4.4:143

Issued January 23, 1909.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—CIRCULAR 143.

A. D. MELVIN, CHIEF OF BUREAU.

MILK AND ITS PRODUCTS AS CARRIERS OF TUBERCULOSIS INFECTION.

U.S. DEPOSITORY

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[Reprinted from the Twenty-fourth Annual Report of the Bureau of Animal Industry (1907).]

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1909.

MILK AND ITS PRODUCTS AS CARRIERS OF TUBERCULOSIS INFECTION.[a]

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In this paper the endeavor will be made to show (1) that tubercle bacilli are frequently present in milk delivered by dairymen to their city customers; (2) that the manner in which tubercle bacilli are eliminated from the bodies of tuberculous cattle offers strong reasons to suspect that they will contaminate milk obtained not only from tuberculous cows but also from healthy cows stabled and milked in a tuberculous environment; (3) that the presence of tubercle bacilli in milk certainly insures their presence in cream, ice cream, butter, and cheese made from it, and (4) that we have no satisfactory reasons for assuming that tubercle bacilli in milk and other dairy products are harmless for human beings.

THE OCCURRENCE OF TUBERCLE BACILLI IN MARKET MILK.

Without reviewing the numerous investigations of older date, or those made in foreign countries, three investigations recently made at Washington, D. C., will amply illustrate the infected condition found when milk, such as is distributed by dairymen in the larger eastern cities of the United States, is examined for the presence of living, virulent tubercle bacilli.

The three investigations were made almost simultaneously, but were quite independent of each other. The first dealt with 223 samples of milk, among which 15, or 6.7 per cent, contained each a sufficient number of tubercle bacilli to cause fatal tuberculosis on the inoculation of guinea pigs. The 15 infected samples were derived from 11 dairies, or 10.7 per cent of the 102 from which milk was tested.[1] [b] The second investigation dealt with 73 samples of milk, among which 2, or 2.7 per cent, contained virulent tubercle bacilli.[22] The number of dairies from which this milk was obtained is not given. In the third investigation (now in progress at this station and the results of which have not heretofore been published) 36

[a] This paper was presented at a meeting of the New York Milk Committee, New York, N. Y., April 11, 1908.

[b] The superior figures in the text relate to the references to literature at end of article.

and New York, respectively, obtain milk are worth anything, the latter city truly has more reasons for uneasiness than the former. Among 1,538 cows in 104 dairy herds supplying milk to Washington, D. C., the tuberculin test revealed 16.9 per cent affected with tuberculosis [22], while the tuberculin test applied to 12,721 cows in 683 herds in 50 counties of New York State showed that little less than one-third of the cows were affected with tuberculosis and that the tuberculous cows were distributed in about two-thirds of the herds.[26] Good reasons can be given for assuming that the percentage for Washington dairy cattle is too low, and relative to the figures for New York, it is well to remember, as Professor Moore, of Cornell, pointed out, that the cows actually tested constitute only about one-half of 1 per cent of the total number in the State—not a sufficient proportion for general deductions. But we will not go astray if we assume that New York milk is at least as badly infected with tubercle bacilli as that of Washington.

SUMMARY OF THE TUBERCULOUS CONDITIONS FOUND IN MARKET MILK.

Before passing on to other matters it may be well to draw some conclusions relative to the tuberculous conditions found in market-milk, as shown from the preceding facts.

1. It has been shown that milk delivered by dairymen to their city customers is frequently infected with living, virulent tubercle bacilli. There is nothing hypothetical, circumstantial, or inferential about this; it is a fact, a plain, experimentally demonstrated fact.

2. The frequency with which regular commercial or market milk contains living, virulent tubercle bacilli is so great that no one who uses raw milk extensively, or as a beverage, can reasonably hope to escape introducing many tubercle bacilli into his body.

3. Dairies that distribute tubercle bacilli in milk as a rule do so intermittently; hence the test of one sample or several samples of milk from one source may give negative results as to the presence of tubercle bacilli without proving the source in question safe.

4. Though the test of a large number of milk samples may give an adequate idea of the proportion of milk that contains tubercle bacilli, it does not provide the necessary material for a satisfactory conclusion as to the proportion of dairies that distribute tuberculous milk. Taken as a whole, the evidence we have indicates that the proportion of infected dairies is at least twice, probably three times, and possibly four, five, or six times as great as the proportion of infected milk.

5. We should give careful attention to both the percentage of infected milk and the percentage of infected dairies. The former indicates more precisely the frequency and intensity with which indi-

vidual persons are exposed to tubercle bacilli in milk and dairy products, while the latter supplies a better idea of the total number of individuals who are exposed.

HOW TUBERCLE BACILLI ARE ELIMINATED FROM THE BODIES OF TUBERCULOUS CATTLE.

The manner in which tubercle bacilli are expelled from the bodies of tuberculous cows is a subject that has received considerable attention at the Experiment Station of the Bureau of Animal Industry during the last three years.[42] [41] [37] The danger from tuberculous persons depends almost entirely on material expelled from their mouths, either as sputum or as an infectious spray of minute droplets. An infectious spray of droplets is also expelled from the mouths of cows during coughing. But cows differ from most persons in one important respect relative to the expulsion of tubercle bacilli. They do not spit; they swallow their sputum, and the tubercle bacilli it contains pass through their bodies and out per rectum with their feces. What this means for the introduction of tubercle bacilli into milk can readily be comprehended when we know that among 172 samples of milk examined last year by the United States Public Health and Marine-Hospital Service 121, or over 70 per cent, contained a visible sediment after standing several hours in the original containers, and that the sediment was composed largely of cow feces.[33]

During the last five or six months I have personally examined the sediment in 66 specimens of milk obtained from the general city supply, and found that even the purest contained a trace of partly digested vegetable matter, probably from the bowels of a cow, while the dirtiest contained about one-fourth of 1 per cent of cow feces. Between the cleanest and the dirtiest there was a regular gradation in the quantity of cow dung present. A sample of milk entirely free from fecal contamination seems to be a rare exception to the general rule. This may not sound very nice, but it has one virtue—it is true.

TUBERCLE BACILLI IN COWS' FECES.

Cows that pass tubercle bacilli from their bowels are not, as might be supposed, well-marked, advanced cases of tuberculosis. I believe most dairymen are too conscientious to sell milk from cows that appear to be sick. Among 12 apparently healthy cows known to be tuberculous only because they had been tested with tuberculin, microscopic examination revealed that 5, or 41 per cent, were passing feces infected with tubercle bacilli. These cows were especially selected from dairy herds for use in an experiment in which a number of recently affected, seemingly healthy, tuberculous cattle were required, and not one among them showed a symptom or a sign of tuberculosis

or other disease that a dairyman or veterinarian could have detected without the tuberculin test. Among 13 cows, of which it was known that they had been affected with tuberculosis eighteen months or more, the microscopic examination of feces revealed that 11, or 84.6 per cent, were passing tubercle bacilli per rectum. These cows, judged from their general appearance, were in much better condition than the cows in many dairy herds; they certainly did not look like sick animals. Among a small lot of well-preserved tuberculous cows that were known to have been affected with tuberculosis three years or more, every one was found to be passing tubercle bacilli per rectum.

To judge from an editorial in the New York Medical Record of March 21, 1908, on the investigations published by R. Rosenberger in the American Journal of Medical Sciences for December, 1907, the occurrence of tubercle bacilli in the feces of tuberculous persons also is so common that their presence may serve to establish an otherwise doubtful diagnosis of tuberculosis.

The infectious, virulent character of tubercle bacilli in the feces of tuberculous cows was proven in several ways, as follows:[42 41 37] (1) By causing tuberculosis in guinea pigs as a result of inoculation with feces; (2) by causing tuberculosis in guinea pigs as a result of inoculation with milk from healthy cows soiled with small quantities of feces; (3) by causing tuberculosis in guinea pigs by inoculating them with butter made from normal milk slightly soiled with feces; (4) by causing tuberculosis among hogs by allowing them access to feces; and (5) by isolating pure cultures of tubercle bacilli from guinea pigs that contracted tuberculosis as the result of inoculation with feces, and causing tuberculosis in cows by inoculating them with these cultures. In one instance the inoculation of a cow with a pure culture of tubercle bacilli, obtained in the manner described, caused an extremely acute form of tuberculosis which ended in death in a few months.

The passage of tubercle bacilli through the body of a cow without loss of virulence was demonstrated by feeding a cow small doses of tubercle bacilli in drinking water and recovering them from her feces. The head of the cow was walled away from her body by a solid board partition and the general conditions were such that nothing could pass behind her from her head without passing through her body. Tubercle bacilli were found not only in the feces, but also in scrapings taken from the rectal mucosa of the cow. The bacilli used in this experiment were of a grade of virulence too low to cause tuberculosis in bovine animals.

The ease with which feces of cows are splashed, sprayed, and otherwise introduced into milk needs no argument, as it has been shown that most of the milk that reaches the consumer is to some extent contaminated with feces. If a single cow in a dairy herd is affected

with tuberculosis it is just as likely to be her feces as those of any other cow which get into the milk; hence the presence of a single tuberculous cow, after she has reached the stage when tubercle bacilli are being eliminated by the way of her bowels, establishes an environment in which milk may become infected with tubercle bacilli. A cow passes about 30 pounds of moist feces each day, and all parts of this may be so infected that tubercle bacilli can be detected in any part on microscopic examination.[41] This is a large amount of infected material to have near the source from which an important article of human food is obtained that is used mostly in a raw state.

UDDER TUBERCULOSIS.

The occurrence of udder tuberculosis among cows is comparatively rare, though it has been estimated that 2 per cent of all tuberculous cows have tuberculous udders.[27] When it does occur the milk will be heavily infected. The possibility of tubercle bacilli passing through the healthy udder of a tuberculous cow when milked is an unsettled question, but if the results obtained from an experiment reported by Doctor Griffith in the appendix of the Second Interim Report of the British Royal Commission on Tuberculosis are reliable this is not only possible, but is of much commoner occurrence than we previously had reason to suspect.[17]

The various facts presented in this short review of the manner in which tubercle bacilli are expelled from the bodies of tuberculous cows give us valid reasons to conclude that it is impossible to obtain milk certainly free from tubercle bacilli, either from tuberculous cows or from healthy cows in a tuberculous environment. The milk of the former may become infected with bacilli eliminated through the udder, and the milk of both the former and the latter may become infected with tubercle bacilli that leave the bodies of tuberculous cattle at both ends—in the feces and in particles of fluid sprayed from their mouths.

THE OCCURRENCE OF TUBERCLE BACILLI IN CREAM, ICE CREAM, BUTTER, AND CHEESE.

On standing or by passage through a centrifuge milk separates into three distinct layers—cream, skim milk, and sediment. The character, appearance, and relative quantity of cream and skim milk are too well known to require description. The small sediment in pure, fresh, normal milk commonly escapes observation; it has a chalky, white appearance and on microscopic examination is seen to be composed mainly of leucocytes and a little epithelium. By experiments made at this station a number of years ago and recently repeated it was found that tubercle bacilli, when they are present in

milk, soon disappear from the skim milk and collect in about equal proportion in the cream and the sediment. This is equally true when cream separates slowly and naturally and when it is forced to the surface quickly by the use of a centrifugal machine.

As tubercle bacilli have a higher and cream has a lower specific gravity than milk, it does not seem unreasonable to infer that the bacilli should gravitate away from the cream and leave it free from infection as it rises to the surface of infected milk. This inference, however, is erroneous; it would no doubt be true if cream were a homogeneous substance and not an aggregation of small spheres or globules. The truth is, the minute bacilli adhere to the relatively large cream globules with a tenacity that can not be broken by the existing difference of specific gravity, even when this is augmented by the application of a centrifugal force strong enough to press the cream into a semisolid almost butterlike mass. Hence, when tubercle bacilli are present in milk they will be present in greater concentration in the cream derived from it, and when ice cream is made from such infected cream it will be just as dangerous to eat it as it is to use infected milk as a beverage.

Cream is the substance from which butter is made, and that butter made from infected cream will also be infected was proved by making butter from infected cream and testing it by guinea-pig inoculations. The cream used in the tests was derived in some instances from the milk of a cow affected with udder tuberculosis and in other instances from normal, healthy milk to which small amounts of feces from a tuberculous cow had been added. As the bacilli that reached the butter were in no instance added directly to the cream, the butter tests show in themselves a perfect transition of tubercle bacilli from milk to cream, and from cream to butter.[41]

An investigation is now in progress at this station to determine the frequency with which market or commercial butter contains tubercle bacilli. The work has only gone far enough to show that some of the butter sold by dealers is very badly infected. If we take the figures supplied by European investigators of the relative frequency with which butter and milk contain tubercle bacilli we may conclude that butter is more frequently infected than milk; in fact, we may say that butter contains tubercle bacilli in sufficient number for their detection thirteen times for every ten times they can be found in milk.[19 12 8]

It is a simple matter to destroy tubercle bacilli in milk and cream by pasteurization. Just how to make infected butter safe is a more difficult problem. For those who are opposed to pasteurization it may be well to call attention to the fact that the United States Public Health and Marine-Hospital Service has shown anew that the benefits derived from it immeasurably outweigh the disadvantages attributed to it.[32]

The precise period of time during which tubercle bacilli remain alive in butter is a question for the solution of which the available data are exceedingly contradictory. Cornet, in his voluminous but excellent work on tuberculosis, published in 1907, points out that Laser could find no live bacilli in butter after twelve days; that Heim records that all tubercle bacilli eventually die in butter and that their maximum life in it is thirty days; that Gasperini found a reduction of virulence after thirty days, though the bacilli were still alive after one hundred and twenty days, and that Dawson, in America, did not observe a reduction of virulence until after the passage of three months, and claims to have produced tuberculosis in a guinea pig by inoculating it with butter eight months old.

The two extremes, twelve days and eight months, are too far apart to be satisfactory; either or both may be wrong; both certainly can not be right. A fairly large difference in the results obtained by different investigators may be reconciled on the assumption that they used very different kinds of butter in their tests. Salt has distinct though weak germicidal properties, hence tubercle bacilli in heavily salted butter may live only a short time, while in unsalted butter they may live and remain virulent indefinitely. Broërs,[8] whose work on tuberculous dairy products seems to be especially reliable, found that tubercle bacilli will live three days in milk even when it has undergone changes that make it unfit for use as food, and twelve days in buttermilk, and that they certainly remain virulent three weeks in butter.

The work of the Experiment Station of this Bureau shows conclusively that no appreciable attenuation of tubercle bacilli in ordinary salted butter occurs in forty-nine days; that they are still highly virulent after ninety-nine days even though the butter has become rancid and moldy, and that they are still alive and capable of causing rapidly fatal tuberculosis in guinea pigs after one hundred and thirty-three days. Mohler, who has made a special study of the length of time tubercle bacilli remain alive in butter held in cold storage under ordinary commercial conditions, has shown that one hundred and fifty-three days is not long enough to kill them.[22]

As light and dryness are the two most potent natural agents for the destruction of pathogenic bacteria, there are good reasons for believing that tubercle bacilli can find no better conditions for their preservation than the bland, moist, opaque character of butter offers.

Cheese has also been found to contain tubercle bacilli; in it they may live from thirty to forty days; the kinds most dangerous are consequently those eaten shortly after they are made. Cheeses which ripen slowly probably contain no living tubercle bacilli when they reach the consumer.[22] [18]

The positive facts at hand all point to the conclusion that cream, ice cream, butter, and cheese invariably contain tubercle bacilli when made from tuberculous milk.

In cream and milk the bacilli can probably be made harmless by pasteurization, and in slowly ripened cheeses they are of little importance; but in ice cream and butter, and in cheese which undergoes no prolonged ripening, it is difficult to know how to protect public health against them. In butter the bacilli are particularly dangerous, because of their long retained vitality and virulence, and because butter is, next to milk, the most important and the most commonly used food product derived from animals.

Unfortunately we can draw no consolation from the fact that oleomargarin is much used as a substitute for butter. As Mohler [23] recently pointed out, the fat from which it is made is not subjected to a temperature high enough to kill tubercle bacilli, and hence oleomargarin or artificial butter may become infected in two ways—by fat derived from tuberculous animals or by the butter and sour milk that enter into its composition. Mohler states that Morgenroth examined 20 samples of oleomargarin purchased in open market and found that 9 of them contained virulent tubercle bacilli.

It is clearly desirable that the cream used in making ice cream and butter, and the milk used in the preparation of rapidly cured cheeses and artificial butter, should either be pasteurized or sterilized before use, or should be obtained from cows that are known to be free from tuberculosis and are stabled, pastured, and milked in a healthful environment.

THE INFECTION OF DAIRY PRODUCTS BY TUBERCULOUS PERSONS.

Though most tubercle bacilli in dairy products probably have a bovine origin, it will not do to ignore the fact that some of them may be derived from tuberculous persons. Persons affected with either pulmonary or laryngeal tuberculosis spray tubercle bacilli from their mouths during coughing, sneezing, and talking, enveloped in droplets of phlegm and saliva. The infectious droplets, when they contaminate articles of food that are not subjected to a sterilizing process before they are eaten, may be a source of great danger. Butter, cheese, and ice cream, unless they are used in the preparation of other articles of food, are not cooked after they pass from the dealer to the consumer, and the same is true to a lesser extent of cream and milk; hence these substances, if they are exposed to an infectious spray of droplets from the mouth of a tuberculous individual at any stage during their manufacture or handling, may serve the purpose of dangerous carriers of tuberculous infection from person to person.

Persons known to be tuberculous should be kept away from articles of food, especially articles of food either commonly or occasionally eaten in the condition in which they are obtained from the dealer.

THE SIGNIFICANCE AND VIRULENCE OF TUBERCLE BACILLI IN DAIRY PRODUCTS.

No one doubted the intertransmissibility of human and bovine tuberculosis before Theobald Smith [44] [45] published his studies on different varieties of tubercle bacilli and Koch made his famous address against the identity of human and bovine tuberculosis.[21] Since that time investigators have been very active with all phases of the tuberculosis question, and the result is a voluminous and varied, also a cumbersome and frequently contradictory, literature. To discuss thoroughly the evidence for and against the view that tubercle bacilli in milk and dairy products have an important significance for public health would fill a large volume, and hence we can give this important subject but scant attention at the present time.

THE INFECTION OF THE LUNG THROUGH THE STOMACH AND INTESTINES.

Unless tubercle bacilli can enter the body through the uninjured mucosa of the digestive tract and cause disease in regions remote to it without leaving evidences of their passage, we may conclude that they are of little importance in food, irrespective of the source from which they are derived. The truth of this statement is so self-evident that many investigators undertook to prove the permeability of the digestive tract for bacteria generally and the tubercle bacillus specifically, and I do not believe that anyone can read the works published by Desoubry and Porcher,[13] Baumgarten,[4] Nicolas and Descos,[28] Ravenel,[31] Dobroklonski,[14] Rabinowitsch,[30] Vallée,[46] Von Behring,[6] Calmette and Guérin,[10] Schlossmann and Engle,[34] [35] Vansteenberghe and Grysez,[47] Petit,[29] the United States Bureau of Animal Industry,[38] [39] the British Royal Commission on Tuberculosis, and others too numerous to mention without coming to the conclusion that tubercle bacilli easily pass through the intestinal mucosa, from there into the lymph stream, and from it into the circulation, to be filtered out by the lung, where they most commonly cause disease.

The most important investigations are probably those of Calmette and his associates, now published in book form. They claim not only that pulmonary tuberculosis by the way of the intestine is possible but also that this is the common mode of infection. They point out that dust particles that enter the lung never penetrate deeper than the first branches of the bronchi, that bacilli may pass through the mesenteric glands as well as the intestinal mucosa without causing

lesions, and that tuberculous processes in the lung never begin in the bronchi or alveoli but always in the capillaries, especially the finest capillary network of the subpleural tissue, etc.[11]

Relative to the beginning of the tuberculous process in the lung, Aufrecht[2] has this to say: "The fact is that the initial changes in the apices in the lung, as I have convinced myself by repeated anatomical examinations, do not spread from the terminal branches of the bronchi." He further says: "I have proved the cheesy tubercle in the lung to be associated, not with the final branches of the air tubes, but with the terminal capillaries of the pulmonary arteries." Köhler,[3] in reviewing Aufrecht's work, justly remarks: "It deserves wide recognition, as it supplies important arguments for a thorough revision of the older views about the development of pulmonary tuberculosis."

The mode of infection with tuberculosis, judged from the best information we have to-day, stamps tubercle bacilli in articles of food as the greatest tuberculous danger to which public health is exposed.

THE INHALATION THEORY OF INFECTION.

The inhalation theory of tuberculosis can have no validity unless it can be shown, first, that it is possible to respire infectious material not only into the larger air passages but deeply into the lung, and second, that infectious material can be suspended in the air without previously losing its virulence.

Anyone who takes the trouble to consider the moist-walled, tortuous passages through which air passes before it reaches the apices of the lung, in which tuberculous disease begins more commonly than elsewhere, and bears in mind that the respiratory process is largely one of diffusion and not altogether one of actively moving currents of air, will probably find reasons to doubt that solid particles of relatively high specific gravity, sustained in a fluid, like air, of much lower specific gravity, can be carried far or deeply into the lung. A theory like the inhalation theory that requires the suspension of physical laws is out of harmony with nature. It is simply untrue, because physical or natural laws can neither be suspended nor violated.

Again, as to infectious material suspended in the air: This must come from one of two sources, namely, the infectious spray from the mouths of tuberculous persons or finely pulverized dust from tuberculous sputum. Flügge[16] and Heymann[20] proved that the earlier work of Cornet, which seemed to show that dust from tuberculous sputum is extremely dangerous, could not be relied upon, and they further proved that dust from sputum is coarse, not easily sustained

in the air, and, at the worst, of very brief infectivity. Cadéac [9] declares that dust ground from tuberculous sputum is harmless to both the digestive and respiratory tracts, and I feel assured from the results obtained with my own work that it is difficult to understand how tuberculous sputum can be converted into virulent tuberculous dust capable of floating in the air.

Flügge and his followers still adhere to the inhalation theory, but in the place of dust they substitute the infectious spray, which, as a little thought will show, can be dangerous to the respiratory tract only in the close proximity of individuals affected with advanced tuberculosis, and hence is not sufficient to explain the frequency with which tuberculosis occurs, even if it could—which is doubtful—penetrate deeply into the lung.

The inhalation theory, critically examined, evidently does not give us reason to undervalue the danger from virulent, fresh tubercle bacilli in milk and dairy products.

CONCLUSION.

And now, in conclusion, a few words about the distinction made between human and bovine tubercle bacilli. When we examine the evidence of the Bureau of Animal Industry, [43] [24] [25] the British Royal Commission on Tuberculosis, and a host of independent investigators whose names it is out of the question to give here, we find, though there may be two morphologically distinct types of tubercle bacilli, that they are connected by transition forms, and that if the two types (one more commonly found in man and the other in cattle, but neither exclusively restricted to man or cattle) really differ in an important way, it is only that the type commoner in cattle is of much higher pathogenic virulence than that commoner in man.

To my mind it is reasonable at present to believe that we have two great sources from which tubercle bacilli are disseminated in a way that is dangerous to public health—tuberculous persons and tuberculous dairy cattle. The former is, no doubt, the more important source, but with regard to the latter we must not forget the significant fact that tubercle bacilli in milk, cream, ice cream, butter, cheese, and oleomargarin are not on floors, or on pavements, or in or on places from which they may or may not enter our bodies; they are located in articles of food commercially distributed among persons to be eaten, in most instances, in a raw state, and therefore are inevitably consumed in large quantities.

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